

Industrial Waste Symposium - American Institute of Chemical Engineers
Regional Meeting - Cleveland, Ohio, May 11, 1948.

Contents of the ORNL Uranium Waste Storage Tanks.

Ionic Analysis of Materials in X-10 Waste Tank.

Radiochemical Analytical Report.

48-5-178

Problem Assignment - Summary of ORNL Decontamination Experience.

Waste Sampling for Problem T.D. 1. 7/15/48.

FLS-23

Excerpts from a Report of the Liquid Process Waste Disposal and
Reclamation Committee, dated 10/7/48.

Interim Report on Chemical Waste System - T.D. -Section II.

National Advisory Committee for Aeronautics, Technical Memorandum
No. 1160, Concerning The Velocity of Evaporation of Small Droplets in
a Gas Atmosphere.

Final Report - Evaporation Entrainment.

Evaporation of Highly Radioactive Wastes from the 1200 Areas.

Decontamination of ORNL Plant Chemical Waste.

Evaporation of ORNL Non-Uranium Bearing Chemical Waste.

Memorandum of D.G. Reid of 6/25/48, regarding Problem Assignment TD-3.
From C.E. Winters to S. McLain.

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WASTE TREATMENT - RADIOCHEMICAL

WASTE EVAPORATION DEVELOPMENT

-2-

CLASSIFICATION CANCELLED

[Signature] 4-28-95
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Single rereview of CCRP-declassified
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Declassification memo of August 22, 1994.

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INTER-COMPANY CORRESPONDENCE

COMPANY CARBIDE AND CARBON CHEMICALS CORP. LOCATION

Post Office Box P.
OAK RIDGE, TENN.

TO F. L. Steahly ✓
LOCATION Room 26 - 706-A

DATE May 25, 1948

ANSWERING LETTER DATE

ATTENTION

COPY TO M. D. Peterson
R. E. Blanco
I. R. Higgins

SUBJECT Industrial Waste Symposium -
American Institute of Chemical
Engineers - Regional Meeting -
Cleveland, Ohio, May 11, 1948.

The regional meeting of the American Institute of Chemical Engineers was attended May 10, 11, 1948, to obtain information pertinent to the problem of treatment of radiochemical wastes. The Industrial Waste Symposium and a meeting of the Industrial Waste Council were attended. Other papers on general topics were heard and visit was made to The General Electric Lighting Institute.

During the Industrial Waste Symposium nine papers were presented. The first three papers dealt with governmental control of stream pollution. Many state pollution control boards have been in operation less than twenty years and have followed a policy of encouraging industry to treat its wastes, rather than dictating stringent regulations. The state pollution boards have found it difficult to define reasonable water conditions. The Tennessee Pollution Control Board has been in operation since 1947, but TVA has been studying stream pollution in the Tennessee Valley since 1938. It was interesting to note that no mention was made of radioactive wastes.

A single paper was presented on management's interest in stream pollution which was broken down into three factors: public relations, legal, and economic.

Two papers were presented in which development programs for liquid and gaseous waste disposal were discussed. Where an air pollution problem exists the general development program is similar to that for liquid wastes. The recommended development procedure was as follows:

- (1) A complete analytical study of all the wastes so that their amounts and compositions and their fluctuations with time may be understood. This will also serve to show conclusively the magnitude of the pollution problem.
- (2) An attempt in the light of the first step to reduce the pollution at the source or to alter its nature so that ultimate treatment processes may be simplified.
- (3) A research study on the two general important aspects of any disposal method: concentration of dilute wastes and the actual treatment of the strong wastes. Various considerations which enter into the selection of a particular method are discussed.
- (4) Cost estimating, by which selection among potential methods may be facilitated.
- (5) Pilot plant design, construction, and operation.

W. K. Eister
5/25/48

Three specific examples of waste disposal developments were discussed which were related to metallurgical and paper industries. Application of precipitation, ion exchange, bacterial filters, thickeners, and lagooning was covered in the discussion.

The meeting of the Industrial Waste Council had as its primary object the selection of subjects and papers for a symposium in November. A request was made for a paper on radioactive waste treatment, but there was no commitment. Some of the men attending the council meeting were:

- R. D. Hoak, Industrial Fellow, Mellon Institute (council chairman)
- V. L. King, Technical Director, Calco Chemical Co.
- H. Bliss, Prof. of Ch. E., Yale University
- M. E. Putnam, Vice-President, Dow Chemical Co.
- R. A. Fisher, Assoc. Prof. of Chem. Eng., Virginia Polytechnic Inst.
- W. W. Hodge, Sr. Fellow, Mellon Institute.

The knowledge gained was of a general nature. The AIChE is now taking an active interest in waste disposal, both liquid and gas, problems and the council is made of responsible men from the major chemical companies. The AEC should be represented.

W. K. Eister
W. K. Eister
Technical Division

WKE:mkw

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To: ~~File~~ *208*

Date: February 8, 1949

From: W. K. Eister

Re: Contents of the ORNL Uranium Waste Storage Tanks

The ORNL uranium waste tanks were sampled 11/23/48 to determine the composition of the sludge and supernatant, preliminary to undertaking a development program for metal recovery. These samples were analyzed and results are shown in the attached table.

It is the current practice to discharge uranyl carbonate solution to these tanks. At the time the tank is full, the uranium is precipitated by the addition of 6.7% by volume of 50% ^{sodium hydroxide} ~~caustic~~. The precipitate is allowed to settle and the supernatant is then discharged through the general radiochemical waste storage system to the river. The tanks now contain approximately 150 tons of uranium of which approximately 80% has been precipitated. This precipitate occupies approximately 20% of the total tank capacity in permanent metal waste storage service. There are now seven tanks with a total capacity of 776,000 gallons being used for storage of uranium wastes. The uranium has been precipitated in Tanks W-3, W-4, W-7, and W-10. Tank W-9 is being used for the storage of metal waste from the Rala process and was not sampled because of its high radioactivity. Tank W-8 is now being used as receiving tank, but will be returned to the radiochemical waste service as soon as sufficient supernatant can be decanted from the precipitated waste tanks. This will reduce the total storage capacity to 606,000 gallons. The last tank is the semi-works waste storage tank (no number) which is now full, and is being held for use in the initial stages of the metal recovery program.

cc: MDP, ~~MDP~~, JAL, CEW, JOD, FRB, FLC,
L. Emlet, P.B. Orr, E.J. Witkowski,
A.F. Rupp, M.T. Kelley

DON'T SAY IT -- WRITE IT

TO W. K. Eister
FROM C. D. Watson

DATE December 4, 1947

Re: Uranium Analysis of Crud and Liquid in Semi-Works Waste Metal Tank

Fluormetric Analysis of Supernatant Liquid

U - 9.64 mg/ml.
Estimated depth of liquid - 41 inches.

Analysis of Precipitate in Bottom of Tank

U - 637 mg/gram of precipitate
Estimated depth of precipitate - 1 foot

CDW:sc

cc: CDW

COPY

11/15/48

DON'T SAY IT -- WRITE IT

TD-12

8

TO W. K. Eister
FROM C. D. Watson

DATE December 1, 1947

Re: Semi-Works Metal Waste Tank

At present, there are 53 inches of sludge and liquid in the storage tank which, according to old reports, constitutes 72.6% of the total tank volume. An analysis of the sludge and liquid indicates the presence of:

Analysis of sludge

Gross β - 3.5×10^6 c/min/gr
 γ - 345 c/min/gr

Analysis of liquid

pH - 9.85
Sp.G - 1.06
Gross β - 760 c/min/ml.
Gross γ - 10 c/min/ml.
Gross α - 7.1×10^3 c/min/ml.

(28)

ORNL Metal Waste Analysis (a)

Tank No.	Phase Sampled	Ionic						Radiochemical			
		U	Na	NO ₃	CO ₃	PO ₄	SO ₄	Gross β	Gross γ	Ru β	Ce β
		mg/ml						cts/ml			
		$\times 10^{-5}$						$\times 10^{-3}$		$\times 10^{-4}$	$\times 10^{-4}$
W3	Supernatant	0.02	110	13.7	33.8	2.4	104	1.9	0.58	8.3	0.06
W4		8.9	2.3	14.5	0.4	0.1	8.3	12.7	2.1	4.0	50.0
W7		0.02	54.2	15.9	29.3	6.0	132	26.0	0.58	9.6	3.2
W10		0.02	74.1	22.4	33.0	8.7	104	29.8	0.9	8.1	4.7
W8(c)		16.1	39.9	15.4	27.8	7.2	227	8.5	1.4	9.4	50.3
		mg/g						cts/g			
		$\times 10^{-6}$						$\times 10^{-3}$		$\times 10^{-5}$	$\times 10^{-6}$
W3	Sludge	539	143	22.8	60	12.5	8.6	19.1	14.0	7.4	11.8
W4		326	190	42.5	51	218	146	4.5	1.33	0.9	1.3
W7		475	170	34.9	67	90	214	3.2	1.2	7.8	0.7
W10		485	164	43.5	49	90	105	8.2	2.4	2.0	4.2

(b) Counting done at 10.18% geometry with no absorber

(c) This tank is used as a collection tank, and no uranium is precipitated here

(a) Ionic results reported 1/4/49 by P.F. Thomason, radiachemical results reported 1/26/49 by C.S. Burros, and the samples were checked by P.B. Orr

(b)

Sr
B

in

10^{-4} $\times 10^{-2}$

4.3 0.52

1.9 1900

7.2 1.7

6.9 4.2

16. 74.1

10^{-5} $\times 10^{-6}$

3.1 1.2

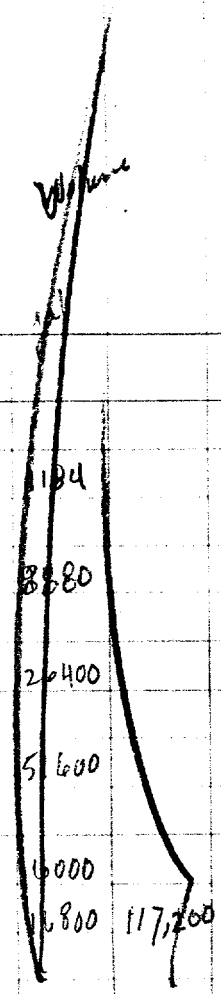
1.2 1.3

1.6 0.7

2.5 1.5

the volume

3/48



INTER-COMPANY CORRESPONDENCE

10

OAK RIDGE NATIONAL LABORATORY

(INSERT
NAME)

COMPANY

CARBIDE AND CARBON CHEMICALS CORP.

LOCATION

Post Office Box P
OAK RIDGE, TENN.

TO
LOCATION

W. Eister

DATE January 4, 1949

ANSWERING LETTER DATE

ATTENTION

COPY TO

F. R. Bruce
F. L. Culler, Jr.
J. C. Davis
M. T. Kelley
P. B. Orr
D. C. Overholt
F. L. Steahly

SUBJECT

Ionic Analysis of Materials
in X-10 Waste Tank

Waste sampled 11/23/48
WSE

<u>Tank</u>	<u>Ion</u>	<u>Result</u>
W3 Supernatant	U	0.022 mg/ml
W4 "	"	8.9 "
W7 "	"	0.019 "
W8 "	"	16.1 "
W10 "	"	0.018 "
W3 Dried sludge	"	539. /g
W4 "	"	326. "
W7 "	"	475. "
W10 "	"	485. "
W3 Supernatant	Na	110 mg/ml
W4 "	"	2.3 "
W7 "	"	54.2 "
W8 "	"	39.9 "
W10 "	"	74.1 "
W3 Dried sludge	"	143 "
W4 "	"	190 "
W7 "	"	170 "
W10 "	"	164 "
W3 Supernatant	NO ₃	13.7 mg/ml
W4 "	"	14.5 "
W7 "	"	15.9 "
W8 "	"	15.4 "
W10 "	"	22.4 "
W3 Dried sludge	"	22.8 "
W4 "	"	42.5 "
W7 "	"	34.9 "
W10 "	"	43.5 "

<u>Tank</u>	<u>Ion</u>	<u>Result</u>
W3 Supernatant	CO ₃	33.8 mg/ml
W4 "	"	0.4 "
W7 "	"	29.3 "
W8 "	"	27.8 "
W10 "	"	33. "
W3 Dried sludge	"	60. "
W4 "	"	51. "
W7 "	"	67. "
W10 "	"	49. "
W3 Supernatant	PO ₄	22.4 mg/ml
W4 "	"	0.1 "
W7 "	"	6.0 "
W8 "	"	7.2 "
W10 "	"	8.7 "
W3 Dried sludge	"	12.5 "
W4 "	"	218. "
W7 "	"	90. "
W10 "	"	90. "
W3 Supernatant	SO ₄	104. mg/ml
W4 "	"	8.3 "
W7 "	"	132. "
W8 "	"	227. "
W10 "	"	104. "
W3 Dry sludge	"	8.6 "
W4 "	"	146. "
W7 "	"	214. "
W10 "	"	105. "

P. F. Thomason
 P. F. Thomason

PFT:ko

B-337

RCR 301

To Mr. J. E. ...

Date 1-26-49

From ... 205

RADIOCHEMICAL ANALYTICAL REPORT

(4) 1-20-49

Results of Analyses of Samples Submitted:

329
494

Sample Number	Our Number	Fraction	Separation Time	cts/m/mi	Fraction	Separation Time	cts/m/mi
W-5 Supernatant	375	Gross 1-14	1-14 10:00 AM	1.91X10 ⁵	W-10 Supernatant	Gross 1-14	2.98X10 ⁵
		Sample 1-14	1-14	2.27X10 ⁴		Sample 1-14	8.07X10 ⁴
		Ce 3 1-14	1-14	640		Ce 3 1-14	475
		2-B 1-21	1-21	1.43X10 ⁵		Ce 3 1-21	2.69X10 ⁵
		2-B 1-18	1-18	52		2-B 1-18	1.13X10 ³
W-6 Supernatant	376	Gross 1-14	1-14 10:00 AM	1.27X10 ⁶			
		Sample 1-14	1-14	3.99X10 ⁴			
		2-B 1-14	1-14	5.10X10 ⁵			
		2-B 1-21	1-21	2.13X10 ⁶			
		2-B 1-18	1-18	1.95X10 ⁵			
W-7 Supernatant	377	Gross 1-14	1-14 10:00 AM	2.60X10 ⁵			
		Sample 1-14	1-14	3.51X10 ⁴			
		Ce 3 1-14	1-14	525			
		2-B 1-21	1-21	1.72X10 ⁵			
		2-B 1-18	1-18	175			
W-8 Supernatant	378	Gross 1-14	1-14 10:00 AM	1.03X10 ⁶			
		Sample 1-14	1-14	1.03X10 ⁶			
		2-B 1-14	1-14	1.03X10 ⁶			
		2-B 1-21	1-21	1.03X10 ⁶			
		2-B 1-18	1-18	1.03X10 ⁶			

recheck
329
494
2833
416

Sample counted at 100% geometry with NC absorber added on total

Remarks:

W-5 - 1-14 - 10:00 AM - only 100% on Sn
W-6 - 1-14 - 10:00 AM - only 100% gross

B-337

RCR

301 (Cont)

To W. H. E. 205

Date

1-26-49

From PCA No. E. 12.205A-10 Waste TankRADIOCHEMICAL ANALYTICAL REPORT

Results of Analyses of Samples Submitted:

Note

Sample Number	Our Number	Fraction	Separation Time	Cts/m/gram DRY WT. cts/m	Fraction	Separation Time	cts/m
11-3 Waste Sludge	373	Gross	1-17 10:30 AM	1.91 x 10 ⁵			
		Ru B	1-19	7.40 x 10 ⁵			
		Ce B	1-19	1.12 x 10 ⁵			
		Co B	1-24	3.13 x 10 ⁵			
		W B	1-19	1.25 x 10 ⁵			
11-4 Waste Sludge	374	Gross	1-17 3:00 PM	4.52 x 10 ⁶			
		Ru B	1-19	3.05 x 10 ⁵			
		Ce B	1-19	1.32 x 10 ⁵			
		Co B	1-24	1.12 x 10 ⁵			
		W B	1-19	1.27 x 10 ⁵			
11-5 Waste Sludge	375	Gross	1-17 3:00 PM	3.12 x 10 ⁶			
		Ru B	1-21	7.5 x 10 ⁵			
		Ce B	1-19	7.16 x 10 ⁵			
		Co B	1-24	1.5 x 10 ⁵			
		W B	1-19	3.07 x 10 ⁵			
11-6 Waste Sludge	376	Gross	1-17 3:00 PM	6.22 x 10 ⁶			
		Ru B	1-21	2.15 x 10 ⁵			
		Ce B	1-19	1.5 x 10 ⁵			
		Co B	1-24	2.1 x 10 ⁵			
		W B	1-19	1.2 x 10 ⁵			

reduction → 7.07 x 10⁵

Sample counted at

% geometry with

total absorber added on

Remarks:

11-3 Waste Sludge - 11-3

OK

~~SECRET~~



RAK RIDGE NATIONAL LABORATORIES
CENTRAL FILES NUMBER
48-5- 178

B-137

Date May 17, 1948

File _____

Subject Problem Assignment - Summary of
XML Decommunization Experience

Those Eligible
To Read The
Attached

By _____

Copy # 9

To _____

F. L. Steahly

Before reading this document, sign and date below:

Name _____ Date _____

Name _____ Date _____

W.K. Easter 7/9/48

~~SECRET~~

0
7 10 A

OAK RIDGE NATIONAL LABORATORY
OAK RIDGE, TENNESSEE

Technical Division

P R O B L E M A S S I G N M E N T

Problem No.: TD - 1

Date: May 17, 1948

Title: Summary of Oak Ridge National Laboratory Decontamination Experience

Object:

To prepare a report in which is summarized and correlated all the experience at the Oak Ridge National Laboratory with the decontamination of gases, liquids and solids.

Discussion:

Decontamination of various materials is a major Atomic Energy Commission problem. It is proposed that the several sites summarize their existing knowledge in this field, after which experimental programs of commission-wide significance can be set up efficiently.

The Oak Ridge National Laboratory experience will be collected partly from the literature, but also from discussions with the individuals involved, since much decontamination here has been done as an incidental part of another program, and therefore has not been adequately reported.

This report is to be issued by August 1, 1948. In order to meet this date, one technical man will be assigned full time to the work immediately. He will be given additional aid as required.

Immediately following the issuing of the summary report, a second brief report will be prepared giving detailed recommendations for future work.

Distribution:

Hawkins, W. M.
Huffman, J. R.
Kyger, J. A.
Lyon, R. N.
McLain, Stuart
Peterson, M. D.
Reid, D. G.
Rucker, C. N.
Steahly, F. L.
Winters, C. E.

Estimated Cost: Labor: 4 man-months
Materials: 0
Total:

Account No.: H417 L

Approvals:

M. D. Peterson

Stuart McLain

July 15, 1948

WKE
7/19/48

To: F. L. Steahly *FUS*

From: F. N. Browder

Subject: Waste Sampling for Problem T.D.1

TC - 1

It is desired to collect as much data as possible on the quantities and rates of the fission products and other ions entering and leaving the tank farm without overburdening the analytical groups. In a conversation today with M. T. Kelley and I. R. Higgins it was decided that the following sampling procedure would best attain the desired results:

1. (a) Take a 1 liter sample from tank W-1 and another from tank W-12 each time each tank becomes full.
(b) On each of these samples run total H^+ , total solids, and gross β and gross γ .
(c) Composite the samples from each tank once per week and run a complete analysis for $gr\beta$, $gr\gamma$, Ru, Zr, Cs, Sr, Cb, TRE, U, Na, Ca, Mg, Al, Fe, Cl, F, CO_3 , SO_4 , PO_4 , NO_3 on both composites of W-1 and Composites of W-12.
2. Take a 1 liter sample from tank W-6 supernate just before the supernate is drawn off. Analyze for all ions and F.P.'s listed in 1 (c) above.

Distribution: 1. M. T. Kelley
2. P. B. Orr
3. I. R. Higgins
4. File

WKE
To: H. D. Peterson

48-11-310 FOST
16
November 19, 1948

From: F. L. Steahly

Excerpts from a Report of the Liquid Process Waste Disposal and
Reclamation Committee, dated October 7, 1948

The accomplishments of the meeting of the Committee on Liquid Process Waste Disposal at Argonne was largely one of organization. Most of the ANL liquid waste comes from Redox semi-works. These wastes are shipped to ORNL.

At Hanford, 23,000,000 gallons of waste are stored. It is calculated that storage and handling costs range from \$0.23 to \$0.34 per gallon. This now approximates \$3,000,000 per year. Cribbs or porous wooden structures vary from some 20 to 30 feet, and the liquid filters directly into the ground. It has been determined that both plutonium and fission products are adsorbed on the sand rather close to the cribbs; plutonium the more so. The penetration of the activity has not exceeded approximately 100' down and 300' laterally from any crib.

At ORNL, uranium wastes are neutralized with sodium hydroxide and sodium carbonate and stored in burial tanks of 170,000 gallon capacity. A two-fold volume reduction was realized when the metal waste was precipitated with excess sodium hydroxide, allowed to settle, and the supernatant decanted to the rest of the waste system. Non-uranium active waste are discharged to the retention basin by a series of 170,000 gallon buried septic tanks. This system is operated to discharge beta activity in the Tennessee Valley water system at concentrations no greater than about one micro-curie per liter.

At Mound Laboratory, a flocculation and carrier sand filter system has been developed through to the pilot plant stage to handle the particular active waste produced there. The Northdale Plant is expected to be operated by October, 1948. This process will reduce the volume of the waste approximately 1,000,000 fold. The discharge to the river will not exceed one count per ml. per minute.

Expressions of the status of the problems are: (a) Waste disposal problems

are less attractive to the majority of research workers in fundamental research; (b) where attempts have been made to solve the problems, the working groups have been subject to the necessities of production. As the consequence, the studies have rarely been completed; (c) there is a possible temptation to a contractor to accomplish this work in a manner just necessary to meet the contractual obligations; consequently, solutions of the problems are temporary, local in character, and potentially hazardous after a period of time; (d) no systematic study or general solution of the problem has appeared; (e) until recently, waste disposal had only a relatively low priority at most of the sites; (f) management has failed to recognize that the problem of waste disposal is comprehensive and involves the entire technology of Pile operations.

General recommendations are: (a) In view of the foregoing, it seems vital that AEC establish a long range work program for studies on liquid waste disposal. It is recommended that the scope of the problem should include: (1) fundamental research in the chemistry of liquid waste disposal; (2) development of methods through the pilot plant stage; (3) assisting the various sites in setting up full scale plants; (4) separating into packages as radioisotopes; (b) The program should be carried on by one or more new contractors or by certain present contractors with supplementary contracts. Consideration of all additional liquid waste disposal problems should be assigned to these contractors; (c) means should be established to interchange and disseminate information and reports throughout the project so that all who are interested have up-to-date data as they are obtained; (d) A means be established to review periodically and to coordinate the foregoing program. This should later be extended to include the review of technology of the plan adopted. Waste disposal should be given a good priority and cooperation should be obtained between AEC, contractors, U. S. Public Health Service, geological and water supply agencies; (e) The commission should encourage every site to critically examine the present practice; (h) Future contracts should embody the requirements

of handling the waste disposal problems. Possible methods are: (a) evaporation if economics make this desirable for a permanent method; (b) carrier precipitant - a mechanical method will have to be developed to separate the slurries from the supernatant; (c) sand filtration might be used as a supplement to precipitation; (d) ion exchange; (e) electrodialysis, worthy of study; (f) metallic displacement; (g) solvent extraction - this might be of low value because it will necessarily add more liquid to an already bad situation. Specific recommendations for immediate work are: (a) the first and immediate problem to be solved is the removal of activity from crib type waste; (b) hot waste; (c) Redox waste - this should be started at once.

FLS:sjh

cc: MDP
FLS
JOD
KE ✓

NOTE:

Consider this a rough draft which will be replaced by a finished report after corrections.

INTERIM REPORT ON CHEMICAL WASTE SYSTEM - I.D. - Section II

8-6-48

1.0 INTRODUCTION

Section II has *recently* been assigned the general problem of disposal of radio-chemical wastes. This report reflects the thoughts of, and the information assembled by, members of Section II at the end of the initial three weeks of effort. All conclusions and recommendations are tentative and subject to revision. The prime purpose of this report is to provide to the personnel attending the discussion of date 8-6-48 (Building 101), convenient and orderly notes of Section II's current position.

It is recognized that much, perhaps all, of what is covered herein may be repetitions to some and may constitute ⁺an endorsement of prior suggestions or thoughts of others.

1.1 Basic Waste Disposal Viewpoints

Initial thought concerning disposal of radio-chemical wastes resulted in such wastes being retained (if possible) under control until activities had decayed sufficiently so that radiated energy per unit volume of waste had fallen to a point equal to or less than a defined level. Such "decayed waste" was then discharged to an open stream.

Current thought is trending to a rejection of this philosophy since -

1. Abuse (generally necessary) is possible by either discharging material at relatively high levels of activity or by dilution of a too-active material immediately prior to discharge, and

1.1 Basic Waste Disposal Viewpoints (Con't.)

2. Evidence of Concentration of the active materials by natural means - adsorption and absorption by clay, biological through metabolism of exposed plant and animal life, etc. - is at hand resulting in the establishment of unsafe conditions from waste material discharged as safe.

Further confirmation of point (2) will require a radical change in basic philosophy governing permitted methods of waste disposal. To wit - that the absolute quantities of activity discharged shall be restricted as much as possible, the ideal being zero activity discharged, regardless of the activity level per unit volume of waste.

Measures that conform to such a change in policy should also develop an additional advantage. Fission materials presently discharged will be retained. As uses are developed for these materials, it may well be that such materials stored now will in the future represent an invaluable supply.

1.2 Immediate Program Objectives

The present waste-disposal system for radio-chemical wastes is approaching inadequacy as the demands upon it increase. It is proposed to improve immediately the adequacy by reducing the volume of waste requiring storage thus permitting longer decay times before discharge. Such a proposal does not conform to the new policy except insofar that most of the activity presently discharged would be dissipated harmlessly while still under control. However, recommended measures to alleviate the present waste-disposal stress are such that they will lead themselves to a logical ultimate solution of the problem, a solution that conforms to the new policy.

1.3 Ultimate Program Objectives

The ultimate objective of the program is to reduce to a practical zero the activity discharged and to convert the active materials to a storable form. Measures to effect, or approach, this Utopian condition will not be emphasized in detail herein except where such possible measures influence decisions or suggestions relative to solving the immediate program objectives.

2.0 SURVEY

Section II personnel assigned to the subject problem realized fully that their combined knowledge of the waste disposal system and related problems constituted little more than an awareness that such existed. It was therefore in order that a survey be first conducted. It was felt that such a survey would be most useful if its impartiality were enhanced by considering only provable facts and neglecting for the time being opinions and conclusions of those already concerned with the problem. While such a practice was followed as much as possible, the complexity of the problem and the lack of certain necessary facts required that opinions of experienced personnel be leaned on heavily.

2.1 Chemical Waste Disposal Process

The entire disposal process may be compared to any industrial process in which raw materials are converted to more useful products. Here, active materials are converted to less active materials (per unit volume) by retention and by dilution with non-active or less-active solutions. When the waste has been converted sufficiently, it is "sold" to White Oak Creek.

The analogy breaks down in one salient sector - that of raw materials utilized. A normal industrial process has inherent in it a measure of control and choice of the raw materials utilized. The disposal system must accept as raw material wastes that are produced as a result of requirements whose importance presumably transcends considerations of the impact of the waste ~~on~~ on the operation of the disposal system.

A measure of control of the raw material is exercised. The bulk of the waste - of low activity - bypasses much of the system. The rest of the waste must be fully processed. The design of the system is such that it is possible through

2.1 Chemical Waste Disposal Process (Cont.)

faulty valves or personnel error to dispatch wastes of both high and low activities to improper destinations.

2.2 Wastes of High Activity

The major sources of high-activity chemical waste are hot pilot plant, semi-works, 706-C and 706-D operations, and 706-A hot sinks. Decantations from metal waste storages are reported to no longer contribute. As a basis of estimate, it is presumed that the listed sources contribute 99% (in terms of activity and of allowance) of the highly active waste that required the full treatment. Further, it is presumed that 95% of the total waste activity is represented by the listed sources.

The wastes of high activity are dispatched to tank 4-5, where they are neutralized and permitted to decay, thence to tank 4-6 for further decay, and thence to the pond system for still further decay. Dilution is also effected in the pond system before discharge to White Oak Creek.

The bulk of this waste passes through tank 4-12 while that contributed by the hot pilot plant reaches 4-5 via the 4-1 and 4-2 by-pass line.

For the purpose of satisfying the immediate objective of relieving the load on the disposal system, the input to 4-5 represents the stream which can be treated with the most telling effect. Its mean value has been determined from available data (appendix A) as 10,600 gal per week with uncertainties at various confidence levels of

± 7,100 gal per week at 95% confidence

± 9,700 gal per week at 99% confidence

± 13,100 gal per week at 99.9% confidence

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2.2 Wastes of High Activity (Cont.)

Considering feed to H-5 as a prime single source, it is not necessary to attempt at this time a break-down of that feed as to sub-sources.

2.3 Wastes of Low Activity

Wastes of low activity are collected from sundry sources and by-pass the tanks H-5 and H-6. Since its total activity contribution is low, and since its high gallonage of more than 300,000 gallons per day make it both of less importance and of greater difficulty to treat, it will be ignored for the present.

3.0 PROPOSAL FOR IMMEDIATE ACTION

It is proposed to eventually subject the feed to tank 4-5 to evaporation after neutralization. Evaporation of the material prior to neutralization would require that considerable acid-resistant surge capacity be provided at considerable expense. It is proposed to utilize 4-5 as a surge tank for neutralized feed to the evaporator. It is proposed to utilize 4-6 as a concentrate receiver and to utilize 4-8 similarly (when it is available) to permit adequate decay of the concentrate before dumping.

3.1 Evaporator Specifications

3.11 Capacity

It is recommended that the evaporator have a capacity of 45,000 gal of feed per week. Considering sodium nitrate content of 4-5 g. per liter in 4-5 neutralized liquor and a saturation solubility of sodium nitrate at 25° C in the neighborhood of 30-100 g. per liter as a basis of estimate, a volume reduction of 95% would be effected - or an evaporative capacity of 42,250 gal per week (317,000 lbs. of water per week). In terms of KKKK BTU's per week, it is ca. 317×10^6 ; in ~~XXXXXX~~ pounds of steam per week, ca. 317×10^3 ; in gallons of butane, 3100 gals per week.

The thermal losses of the evaporator chosen will increase the heat requirements.

3.12 Design of Evaporator

An evaporator for interim pilot plant service is under design (by F. L. Guiler and associates) whose essential parts are a 9 ft. by 7 ft. tank-body of 2300 gallon capacity, three coils operating in parallel, and three condensers in parallel. The evaporator body and the coils are of 309-Cb stabilized stainless steel.

3.12 Design of Evaporator (Con't.)

The coils are separately fed by steam and condensate removal is separate, permitting removal of each coil separately for maintenance. The designers plan to operate with the evaporator body 1/3 full.

Auxiliary tankage includes a feed tank and a neutralization tank, each of 2100 gallon capacity and a condensate tank of 2100 gallon capacity. Feed may or may not be neutralized.

Design DESIGN evaporative capacity is 4000 gallon per day but the designers state this can be increased by addition of coils.

Analysis of W-6 contents indicate it is probably a high-sealing material under evaporation. For this reason, it is proposed that submerged combustion evaporators be investigated as the design least likely to result in sealing difficulties.

Submerged-combustion design possesses other advantages for this service. Its maintenance requirements are low since body construction can be of durable brick. If serious trouble develops with the burner, it can be discarded and replaced retired to the burial grounds at a minimum cost considering similar difficulties with other designs. Further, its thermal efficiency is high.

3.13 Condenser Requirements

It will be necessary to design a low entrainment evaporator condenser system to attain single stage 10^5 decontamination. A literature search on this problem is currently underway.

3.2 Process Utilizing Evaporator

Waste requiring treatment could be received and neutralized in W-5 from which it would be pumped to the evaporator either directly or through a feed tank. The condensate would be discharged to the pond system. The concentrate would be discharged to tank W-6 or Tank W-8. Concentrate would feed into one tank until

3.2 Process Utilizing Evaporator (Cont.)

the tank was full. The full tank would not be dumped until a day or two before it was needed. The average decay time as concentrate is easily calculated.

3.21 Decay Time

Time required to fill tank at rate of 2,250 \bar{M} gals concentrate per wk.

$$\frac{170,000}{2250} = 75 \text{ weeks}$$

$$\frac{75}{2} = \text{average time during tank fill-up} = 37.5 \text{ weeks}$$

$$\text{hold up time while other tank fills} = 75 - 2 = 73 \text{ weeks}$$

$$37.5 + 73 = \text{ca. 110 weeks decay time as concentrate.}$$

The estimate of 110 weeks decay time is minimum since the mean weekly concentrate production is less than the 99.9 % certain maximum of 2250 gallons per week.

The concentrate may ~~NE~~ never be discharged to the pond system.

Ultimate plans may call for drying the concentrate.

112.

3.3 Provision for Break-down

Note that inherent in all the estimates is ample provision for evaporator break-down. The capacity of the evaporator is such that W-5 should always be maintained at a low level, thus providing about $5 \frac{1}{3}$ average weeks surge capacity or 160,000 gallons. Note from the data in Appendix A that the worst 4 week period only equaled that capacity. A 4-week allowance for major repairs should be ample.

The evaporator capacity is such that build-ups of evaporator feed may quickly be reduced.

In event of an emergency even worse than that requiring a 4-week shut down during maximum feed build-up, the decaying concentrate tank could be dumped ahead of

3.3 Provision for break-down

schedule to provide additional feed storage capacity.

It is considered doubtful that a second evaporator need be provided for stand-by service.

3.4 Patrol of Source Areas

A regular patrol of major sources of waste by personnel of the department charged with operation of the disposal system could guard against the misuse of the hot waste system.

4.0 ULTIMATE PROGRAM PROPOSALS

Proposals to essentially eliminate the discharge of any active material in the waste are here presented briefly.

4.1 Crystal Cropping

It is proposed that the feasibility, by controlled crystallization of the evaporator concentration, of cropping non-active materials be thoroughly investigated. Rough extraction and purification of wanted materials might possibly be effected also.

4.2 Solvent Extraction and Ion Exchange Processes

Specific materials might be extracted from the evaporator concentrate by application of solvent extraction processes, ion exchange processes, or some other process not yet developed.

4.3 Concentrate Drying

It is proposed that the evaporator concentrate be spray dried, the dry material to be stored for future extraction of useful materials - or just stored permanently. The condensate from spray drying would be returned to the evaporator feed stream.

4.4 Redesign of Waste Collection System

It is proposed that the waste collection system be re-designed to permit a better segregation of waste types.

II 4.41 Dispatching Tanks

It is recommended that major sources of active waste be provided with individual storage tanks to hold one average weeks waste production (by the particular source). It is further proposed that authority to dispatch such waste to the disposal system be vested in those responsible for the operation of the disposal system to permit proper timing by the disposal system operators

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Appendix A - Mean Feed to Tank 4-5

A barium run is made about every 7 weeks. A sample period of 21 weeks was chosen. It was therefore necessary to find the most recent 21-week period during which 3 barium runs were made. Such a period occurred between Nov. 2, 1947 and March 27, 1948.

Listed are the reported inputs to tank 4-5 over that period. Barium run dates were Nov. 9 to Nov. 22, Jan. 14 to Jan. 23 and Feb. 25 to Mar. 12. The tank feeds are listed chronologically down the columns. Those during barium runs are underlined.

In gallons per week

9,300	10,000	34,800
<u>45,600</u>	3,000	44,400
<u>32,200</u>	43,000	<u>42,200</u>
37,000	<u>30,900</u>	<u>38,400</u>
57,500	<u>42,200</u>	<u>32,400</u>
31,000	3,600	51,600
18,000	30,000	13,200

The mean input is 30,600 with uncertainties at various confidence levels listed.

- at 95% confidence level $\pm 7,100$ gal per week
- at 99% confidence level $\pm 9,700$ gal per week
- at 99.9% confidence level $\pm 13,100$ gal per week

Using

$$s^2(\bar{x}) = \frac{\sum (x_i - \bar{x})^2}{n(n-1)}$$

For the analysis of the variance of the mean

and using the expression

$$\pm t(0.05 \text{ or } 0.01 \text{ or } 0.001, n-1 = 20) \times s(\bar{x}) \text{ uncertainty in the mean.}$$

Values of the "t" were obtained from a table.

Fuchs
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TECHNICAL MEMORANDUM

No. 1160

CONCERNING THE VELOCITY OF EVAPORATION OF SMALL DROPLETS
IN A GAS ATMOSPHERE

By N. Fuchs

Physikalische Zeitschrift der Sowjetunion
Vol. 6, 1934



Washington
August 1947

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TECHNICAL MEMORANDUM NO. 1160

CONCERNING THE VELOCITY-OF EVAPORATION OF SMALL DROPLETS

IN A GAS ATMOSPHERE¹

By N. Fuchs

SUMMARY

The evaporation velocity of liquid droplets under various conditions is theoretically calculated and a number of factors are investigated which are neglected in carrying out the fundamental equation of Maxwell. It is shown that the effect of these factors at the small drop sizes and the small weight concentrations ordinarily occurring in fog can be calculated by simple corrections. The evaporation process can be regarded as quasi-stationary in most cases.

The question at hand, and also the equivalent question of the velocity of growth of droplets in a supersaturated atmosphere, is highly significant in meteorology and for certain industrial purposes. Since the literature concerning this is very insufficient and many important aspects either are not considered at all or are reported incorrectly, it seems that a short discussion is not superfluous. Especial consideration will be given to the various assumptions and neglects that are necessary in deriving the fundamental equation of Maxwell. The experimental work available, which is very insufficient and in part poorly dependable, can be used as an accurate check on the theory only in very few cases.

I. THE FUNDAMENTAL EQUATION

The theory of the evaporation process in a gas atmosphere owes its beginnings to Maxwell (reference 1) and Stefan (reference 2). The theory rests on the assumption that the vapor in the immediate neighborhood of the liquid surface is completely saturated, and that consequently the velocity of evaporation depends simply on the velocity of diffusion of the vapor into the surrounding space. This viewpoint was experimentally

*The term "Velocity" as used in this report corresponds to "rate" as currently used in American reports.

¹From *Physikalische Zeitschrift der Sowjetunion*, vol. 5, 1934, pp. 224-243.

substantiated by Stefan himself, and also by Winkelmann (reference 3) and except for a limitation later discussed further, is regarded as an established fact.

Since diffusion and heat conduction are physically related concepts and are also completely equivalent processes from a mathematical viewpoint, use can be made of the heat transfer theory, which has been worked out in great detail, in the theoretical calculation of the velocity of evaporation.

Now, turn to the derivation of the fundamental equation for the velocity of evaporation of small droplets in a gas atmosphere. To do so, a series of simplifying assumptions must be made. Later, these assumptions will be examined one by one and corresponding corrections will be introduced in the fundamental equation. The assumptions are:

1. The drop is spherical.
2. There is no motion of the drop relative to the gas atmosphere.
3. The atmosphere extends unbounded in all directions.
4. The atmosphere is all at the same temperature and pressure. The lowering of temperature of the drop is neglected because of the evaporation.
5. The evaporation process is stationary.
6. The vapor is saturated on the surface of the drop.
7. The vapor pressure of the drop is vanishingly small in comparison with the total pressure.

Since the process takes place spherically, Fick's law,

$$\frac{\partial c}{\partial t} = D \Delta c \quad (1)$$

expressed in spherical coordinates, becomes

$$\frac{\partial (cr)}{\partial t} = D \frac{\partial^2 (cr)}{\partial r^2} \quad (2)$$

In the stationary instance this reduces to

$$\frac{\partial^2 (cr)}{\partial r^2} = 0 \quad (3)$$

or, integrated

$$c = A + \frac{B}{r} \quad (4)$$

If c_0 is the concentration of the saturated vapor, and c_1 the concentration at infinite distance from the drop, then there is obtained:

$$c - c_1 = (c_0 - c_1) \frac{a}{r} \quad (5)$$

where a is drop radius.

The amount of substance (expressed in moles) diffusing away per unit time is (reference 1),

$$I_0 = -4\pi D r^2 \frac{dc}{dr} = 4\pi a D (c_0 - c_1) \quad (6)$$

Therefore the velocity of evaporation of the drop in a gas atmosphere, as opposed to evaporation in a vacuum, is proportional to the diameter and not the surface. (Results are substantiated by Sresnewski (reference 4) and Morse (reference 5.) Topley and Whytlaw-Gray (reference 6) checked experimentally formula (6). Since

$$I_0 = -\frac{\gamma}{M} \frac{dv}{dt} = -\frac{2\pi a \gamma}{M} \frac{d(a^2)}{dt} \quad (7)$$

where

γ liquid density

v drop volume

M molecular weight of liquid

Then, from equations (6) and (7)

$$\frac{d(a^2)}{dt} = -\frac{2(c_0 - c_1)MD}{\gamma} = k, \text{ a constant,} \quad (8)$$

that is, the drop surface changes linearly with time. Here, equation (6) is assumed to hold even for constantly changing drop size. This is true, down to a certain drop size, for the most widely different experimental conditions.

A correction must be applied to equation (6) if the previous assumptions are not fulfilled. Also, without loss of generality, c_0 can be written for c_1 . Then equation (5) becomes

$$c = c_0 a/r \quad (5')$$

and equation (6)

$$I_0 = 4\pi a D c_0 \quad (6')$$

II. FINITE VAPOR PRESSURE

First, let fall the assumption that the vapor pressure of the liquid is vanishingly small compared to the gas pressure. Since the total pressure is everywhere the same, so must there be a concentration lowering of the gas equal and opposite to that of the vapor. Since, however, in the stationary state no flow of the gas can take place, so must the diffusion of the vapor be compensated by a convection current of the gas mixture directed toward the outside. The velocity of this current will be determined by the following equation:

$$c'u = D' \frac{dc'}{dr}$$

where the concentration of the gas has been designated as c' , and the diffusion coefficient of this in the vapor as D' . But $D' = D$ and

$\frac{dc'}{dr} = -\frac{dc}{dr}$. Therefore

$$u = -\frac{D}{c'} \frac{dc}{dr} \quad (7')$$

The total vapor flow then becomes

$$I = -4\pi r^2 \left(D \frac{dc}{dr} - cu \right) = -4\pi r^2 D \frac{dc}{dr} \left(1 + \frac{c}{c'} \right) \quad (8')$$

If C is designated as $c + c'$, the constant total molar concentration, then

$$I = -\frac{4\pi r^2 DC}{C - c} \frac{dc}{dr}$$

from which (reference 2)

$$I = -4\pi aDC \ln\left(1 - \frac{c_0}{C}\right) \quad (9)$$

(Concentration of saturated vapor is c_0 .) (For $r = \infty$, $c_1 = 0$.)

Expansion of the logarithm leads to

$$I \approx 4\pi aDc_0 \left(1 + \frac{c_0}{2C}\right) = I_0 \left(1 + \frac{c_0}{2C}\right) \quad (10)$$

As a first approximation, the percent errors involved in using (6') instead of (10) is $c_0/2C$. For water vapor at 20° C and atmospheric pressure, this amounts to only 1.2 percent.

III. LIMITED SPACE OF EVAPORATION

Here will be considered only the case of absorbing walls, on which there obtains a constant vapor pressure. With nonabsorbing walls the process is obviously not stationary and will be dealt with in another section.

If, for the sake of simplicity, it is assumed that the vessel is spherical and that the drop is located in the center, then there is obtained, instead of (5) and (6),

$$c = c_R + \frac{(c_0 - c_R)a}{r} \frac{R - r}{R - a} \quad (11)$$

$$I = \frac{4\pi(c_0 - c_R)aD}{1 - \frac{a}{R}} = \frac{I_0}{1 - \frac{a}{R}} \quad (12)$$

where R is the vessel-radius, and the constant vapor concentration at the wall is designated by c_R . A vessel large with respect to the drop size has practically no influence on the velocity of evaporation.

IV. THE LOWERING OF TEMPERATURE OF THE DROP BECAUSE OF ITS EVAPORATION

This correction is the most important for volatile liquids. For the derivation of this, first of all, the radiation of heat and convection currents will be neglected, and only the flow of heat to the drop by conduction will be considered. If it is also postulated that the coefficient of heat conduction is constant at all points of the gas atmosphere - that is, independent of the temperature or composition of the gas-vapor mixture within certain limits - then, in the stationary case the distribution of the temperature and the magnitude of the heat flow are expressed, respectively, in the same formulas as the distribution of concentration and the velocity of evaporation, and can be expressed as:

$$T_1 - T = \frac{a}{r} (T_1 - T_0) \quad (13)$$

$$Q = 4\pi Ka (T_1 - T_0) \quad (14)$$

where T and T_1 are the temperatures at r and at infinite distance, and T_0 is the drop temperature with K the coefficient of heat conductivity and Q the heat flow per unit time. The heat used in evaporation, however, is:

$$Q' = I_0 l = 4\pi a l D c_0 \quad (15)$$

(l = molar heat of evaporation) where D is assumed independent of temperature.

(Translator's Note: By virtue of its evaporative potential, a drop initially at the same temperature as its surroundings, if quite volatile, will evaporatively self-cool to a temperature below that of its surroundings such that the heat flow from the outside will supply the latent heat of vaporization.)

In the stationary state Q must equal Q' or (reference 1),

$$T_1 - T_0 = \frac{l D c_0}{K} = \frac{l D c_0}{K R T_0} \quad (16)$$

since Maxwell states $c_0 = \frac{P_0}{R T_0}$. But T_0 and P_0 are also related by the vapor pressure equation

$$p_o = f(T_o) \quad (17)$$

By (16) and (17) T_o and p_o are clearly determined and are independent of the size of the drop. The above-mentioned linear relationship (equation (8) between the surface of the drop and the time remains undisturbed by the lowering of the temperature.

In order to compare these formulas with experimental results, or to determine the value of the diffusion coefficient, (16) and (17) are not solved, but there is obtained directly from (14), (15), and (7)

$$T_1 - T_o = \frac{I_o l}{4\pi K a} = \frac{\gamma l}{2MK} \frac{d(a^2)}{dt} \quad (18)$$

From the measured values of $\frac{d(a^2)}{dt}$ there can be calculated $T_1 - T_o$, T_o and p_o (from (17)), and, finally, D (from (8)).

For small $T_1 - T_o$ equations (16) and (17) can be solved by means of the Clausius-Clapeyron equation, and the following explicit expression for the temperature lowering can be obtained:

$$I = I_o \left(1 - \frac{l^2 D c_1}{K R T_1^2} \right) \quad (19)$$

This correction was used by Topley and Whytlaw-Gray (reference 6) in their investigation of the rate of evaporation of small spheres of iodine by means of a spiral-spring balance. The values of D obtained in the manner described at various temperatures (14° to 30° C) differ only about 1 to 3 percent from values determined directly. The temperature lowering of the small spheres in this investigation was, however, comparatively small (0.3° to 0.5° C).

Similar measurements were recently made by Houghton (reference 7) on water droplets ($a = 50\mu - 300\mu$), which were hung on very fine glass fibers. The decrease in volume of the drop was measured microscopically. The conventional psychrometric formula which Houghton used for calculating the temperature lowering led, of course, to markedly varying values of D . Since, in this case, the temperature lowering has a significant value (about 15° at 25° C and in dry air), a study must be made of the dependence of D on temperature. As a first approximation, the assumption can be made that the coefficient of heat conductivity is constant, as is the distribution of temperature (13), and then the average value of $1/2(K_1 + K_o)$ can be taken for K in (16). The integration of equation (6) yields - for a variable D :

$$I = \frac{4\pi c_0}{\int_a^{\infty} \frac{dr}{Dr^2}} \quad (20)$$

By differentiating (13), there is obtained:

$$\frac{dr}{r^2} = \frac{dT}{a(T_1 - T_0)}$$

For D it can be said, approximately,

$$D = D_0 \left(\frac{T}{T_0} \right)^2 \quad (21)$$

(Translator's Note: Other investigators give

$$\frac{D}{D_0} \sim \left(\frac{T}{T_0} \right)^{3/2}$$

See, for example, Sherwood, "Absorption and Extraction," McGraw-Hill Book Co., Inc., 1937.)

By substitution of this expression in (20) there is obtained:

$$I = \frac{4\pi c_0 a (T_1 - T_0)}{\int_{T_0}^{T_1} \frac{dT}{D}} = 4\pi c_0 a D_0 \frac{T_1}{T_0} = 4\pi c_0 a \sqrt{D_1 D_0} \quad (22)$$

(where D_1 corresponds to temperature T_1).

Therefore D must be replaced in equation (6) by the geometric mean $\sqrt{D_1 D_0}$; but for small temperature lowering the ordinary arithmetic mean can be used.

Use of that curve will now be made in Houghton's results, which shows the evaporation of a water droplet at 21.7°C in perfectly dry air, and corresponds to a $\frac{d(a^2)}{dt} = 3.38 \times 10^{-5}$ square centimeters per second. If there is set, in equation (18), $\gamma = 1$, $l = 10600$ calories, $2M = 36$, $K^{130} = 6.0 \times 10^{-5}$ cal/cm sec $^\circ$ (reference 8) then,

$T_1 - T_0 = 16.56^\circ$; $T_0 = 5.14^\circ \text{ C}$; $c_0 = 3.79 \times 10^{-7}$ moles per cubic centimeter from which, according to (8), where $c_1 = 0$,

$$D = \sqrt{D_0 D_1} = 0.248$$

Finally, there can be calculated for D at 0° C , according to (21), the value $D = 0.224$, which is a good approximation of the tabulated value 0.220 (reference 9). On the other hand, the curves given by Houghton for evaporation in partially saturated air show strongly varying values of D ; there could be considerable measurement error in the determination of the vapor concentration.

In order to evaluate the magnitude of the heat transfer by radiation, which has been neglected, it will be assumed that the drop and also the walls of the vessel are perfect black bodies. Then the heat influx to the drop by radiation can be expressed by the Stefan-Boltzmann equation:

$$Q_1 = 4\pi a^2 \sigma (T_1^4 - T_0^4)$$

If this equation is divided by (14), then:

$$\frac{Q_1}{Q} \approx \frac{4a\sigma T_1^3}{K}$$

(Translator's Note: This approximation assumes that $T_0 < \frac{T_1}{4}$.)

By substituting the values $\sigma = 5.7 \times 10^{-5}$ and $K = 2540$ absolute units, (air at $T_1 = 290^\circ \text{ K}$), there is obtained:

$$\frac{Q_1}{Q} = 2.19a$$

Therefore, the neglecting of radiated heat in the calculation of the temperature lowering can introduce an error of only 2 percent at most for $a = 100 \mu$. According to an investigation of Langmuir (reference 10) the effect of thermal convection can also be neglected.

V. CONCENTRATION JUMP AT THE DROP SURFACE

The unanswered question of Stefan and Winkelmann concerning the exact value of the concentration of vapor at the surface of an evaporating body can be solved in the usual manner of gas kinetics. Quite analogous to the changes of velocity and temperature, respectively, present at a solid wall, there is a jump in concentration upon the start of evaporation - which was first reported by Langmuir (reference 11). This jump at atmospheric pressure generally has a vanishing value on a flat surface, but it is quite otherwise in the case of small drops, when the diameters become comparable with the mean free path λ of the vapor molecules.

One of the molecules escaping from the surface will be, after traveling the distance λ , at an average distance Δ from the surface. The ratio $\beta = \Delta/\lambda$ certainly depends on the value of λ/a and lies within the limits $2/3$ (for $a \gg \lambda$) and 1 (for $a \ll \lambda$). Per unit time $4\pi a^2 v c_0$ molecules escape from the drop surface, if $v c_0$ is the number of molecules impinging on a square-centimeter-per-unit time at a gas concentration c_0 . Here the usual presumption is made that the coefficient of accommodation of the vapor molecules on the liquid surface is exactly 1. At the same time $4\pi a^2 v c_1$ vapor molecules condense on the same surface, where c_1 is the vapor concentration at a distance Δ from the surface. Therefore, the resultant amount evaporating is equal to $I_1 = 4\pi a^2 v m (c_0 - c_1)$. This must equal the amount carried through by diffusion, $I_2 = 4\pi (a + \Delta) D c_1$. If there is substituted for D the expression of Meyer $4/3 \lambda v m$, then there is obtained:

$$c_1 = \frac{c_0}{1 + \frac{4/3 \lambda (a + \beta \lambda)}{a^2}} \quad (23)$$

$$I = \frac{I_0}{1 + \frac{4}{3} \frac{\lambda}{a} - \frac{\beta \lambda}{a + \beta \lambda}} \quad (24)$$

For the larger small drops ($a \gg \lambda$, $\beta \approx \frac{2}{3}$), therefore:

$$I \approx \frac{I_0}{1 + \frac{2}{3} \frac{\lambda}{a}} \quad (25)$$

However, for the very small drops ($a \ll \lambda$, $\beta \approx 1$)

$$I \approx \frac{4\pi a D c_0}{1 + \frac{4}{3} \frac{\lambda}{a} - \frac{\lambda}{a + \lambda}} = \frac{4\pi a^2 c_0 v_m}{1 + \frac{3}{4} \frac{a}{\lambda} - \frac{3}{4} \frac{a}{a + \lambda}} \approx \frac{4\pi a^2 c_0 v_m}{1 + \frac{3}{4} \frac{a^2}{\lambda^2}} \quad (26)$$

Therefore, very small drops evaporate in a gas atmosphere with the same velocity as in a vacuum. Moreover, in solving equation (24) it is possible also to start from the velocity of evaporation in a vacuum, in that this is multiplied by the probability that an evaporated molecule does not again encounter the drop in its subsequent motion.

Equation (25) shows that the usual linear change of drop surface holding for small drops is no longer valid. Since λ at atmospheric pressure is of the order of 10^{-5} centimeter, the correction calculated by (25) is already 7 percent for $a = 1\mu$, and 40 percent for $a = 0.1\mu$. A decrease in the rate of change of the drop surface, which began to be noticeable at $a \approx 1\mu$, was actually observed by Speakman and Sever (reference 12) on a series of organic compounds. The explanation by these authors that this phenomenon was due to a lowering of the vapor pressure of the drop by dissolved nonvolatile impurities, can perhaps also be true. Unfortunately, the curves presented in the above-mentioned book do not permit a quantitative comparison with equation (25).

In a recent work by Woodland and Mack (reference 13) an opposite observation was made — an increase in $d(a^2)/dt$ upon diminishing the size of the drop. The cause of this discrepancy must lie in something else; in the proposed explanation of their findings, however, these authors come to very erroneous conclusions, such as the presence of a layer of vapor, 0.5μ thick, surrounding the droplet, and so on.

It is easy to see that the correction of the change of vapor pressure as a consequence of the curvature of the surface and the charge of the drop can be neglected in comparison with the correction just discussed.

VI. NONSTATIONARY PROCESS

The exact calculation of the velocity of evaporation in the nonstationary case meets, in general, the greatest mathematical difficulties. Fortunately, in practice most of the conditions of the process can be regarded as quasi-stationary (that is, the process has at every instant the same velocity as in the stationary state which corresponds to the boundary conditions at that instant) as follows:

Into the infinitely extended gas atmosphere, in which the vapor concentration is everywhere zero, a drop of radius a is introduced at time $t = 0$. Apart from the jump in concentration at the surface, and so forth, the primary problem is the solution of the differential equation (2) with the following boundary and initial conditions, respectively:

$$c = 0 \quad \text{at} \quad t = 0 \quad \text{and} \quad r > a,$$

$$c = c_0 \quad \text{at} \quad t > 0 \quad \text{and} \quad r = a.$$

The solution is given by the following expression:

$$c = \frac{2c_0a}{r\sqrt{\pi}} \int_0^{\infty} e^{-x^2} dx$$

$$\frac{r-a}{2\sqrt{Dt}}$$

From this there is obtained,

$$I = -4\pi a^2 D \frac{dc}{dr} = 4\pi a D c_0 \left(1 + \frac{a}{\sqrt{\pi Dt}}\right) = I_0 \left(1 + \frac{a}{\sqrt{\pi Dt}}\right) \quad (28)$$

($r=a$)

Since $\sqrt{\pi D}$ at atmospheric pressure is of the order of magnitude 1, there can be substituted $I \approx I_0 \left(1 + \frac{a}{\sqrt{t}}\right)$. The correction amounts to only 1 percent after 1 second, even in a heavy fog ($a = 100\mu$). In order to decide to what extent the evaporation of a drop can be regarded as stationary, the time interval t_1 is compared, after which the correction term $a/\sqrt{\pi Dt}$ reaches a definite small value Δ , with the time t_2 necessary for complete evaporation of the drop.

Thus

$$t_1 = \frac{a^2}{\Delta^2 \pi D}$$

and from (8)

$$t_2 = \frac{a^2 \gamma}{2MDc_0}$$

therefore

$$\frac{t_1}{t_2} = \frac{2c_0M}{\Delta^2\pi D\gamma} \quad (29)$$

If there are substituted the values $\Delta = 0.01$, $M = 18$, and $c_0 = 3.79 \times 10^{-7}$ moles per cubic centimeter, which correspond to the evaporation of water drops in dry air at 21.7°C (see above), then

$$\frac{t_1}{t_2} = 0.043, \text{ or in other words, even after the course of the twentieth}$$

part of the time of total evaporation the velocity of evaporation exceeds the velocity corresponding to the stationary state by only 1 percent. In damp air or with less volatile liquids the approximation to the stationary state is realized still more quickly. The effect of the gradual reduction of drop size which was left unconsidered in the discussion will be described further.

For the calculation of the velocity of evaporation of droplets of solutions, the nature of the variation of vapor pressure at the surface with time becomes important. If it is assumed that the concentration of the saturated vapor is a time function $c(t)$, then, instead of (27), there is obtained

$$c = \frac{2a}{\sqrt{\pi r}} \int_0^\infty c \left[t - \frac{(r-a)^2}{4Dx^2} \right] e^{-x^2} dx \quad (\text{reference 15}) \quad (30)$$

$$\frac{r-a}{2\sqrt{Dt}}$$

which can be easily verified. From this is obtained (omitting the repetition of the somewhat detailed calculations):

$$I = -4\pi a^2 D \frac{\partial c}{\partial r} = 4\pi a D c(t) \left[1 + \frac{a}{\sqrt{Dt\pi}} \frac{c(0) + 2t \int_0^1 c'[t(1-x^2)] dx}{c(t)} \right] \quad (31)$$

(r=a)

where c' means dc/dt .

Whether or not an approximation to the stationary state is possible here depends on the special form of $c(t)$. In general, the following can be said; wherein it is necessary to take into account the most important practical cases of the decrease in $c(t)$ with time. In order to reach a good approximation of the stationary state, it is sufficient that $a/\sqrt{Dt\pi}$ increase by a definite amount Δ after a time interval t , which is small relative to the interval t_3 , meanwhile the factor times $a/\sqrt{Dt\pi}$ remains of the order of magnitude of 1. If $|c'(t)|$ is designated by $f(t)$ and it is noted that:

$$c(t) = c(0) + \int_0^t c'(t)dt = c(0) - t \int_0^1 f(tx)dx$$

then this factor takes the following form:

$$F = \frac{c(0) - 2t \int_0^1 f[t(1-x^2)]dx}{c(0) - t \int_0^1 f(tx)dx}$$

With decreasing $f(t)$

$$\int_0^1 f(tx)dx = \int_0^1 f[t(1-x)]dx > \int_0^1 f[t(1-x^2)]dx$$

and for t_3 the interval will be taken after which $c(t)$ is half of its original value, that is, the root of the equation

$$\frac{c(0)}{2} = t \int_0^1 f(tx)dx$$

In this interval $F < 2$.

With increasing $f(t)$, that value of t can be chosen for t_3 such that F vanishes; $c(t)$ will then not reach $1/2c(0)$. In this interval $F < 1$. It is sometimes more convenient to use $t_3' < t_3$ instead of t_3 ; so that the equation $c(0) = 2tf(t)$ is satisfied.

Now, consider the continuous diminishment of the evaporating droplet due to disturbance of stationariness. The strict treatment of this problem is extremely complicated; as an approximate estimate use can be made of

the following consideration. If there is originally a stationary state corresponding to drop radius a and vapor concentration c_0 , then the states arising from a decrease in a of Δa at constant c_0 , and a decrease in c_0 of Δc_0 at constant a , respectively, are given by the following expression:

$$c = \frac{1}{r} \left\{ c_0 a - c_0 \Delta a \left[1 - \psi \left(\frac{r - a + \Delta a}{2\sqrt{Dt}} \right) \right] \right\}$$

and, respectively,

$$c = \frac{1}{r} \left\{ c_0 a - a \Delta c_0 \left[1 - \psi \left(\frac{r - a}{2\sqrt{Dt}} \right) \right] \right\}$$

(ψ = Gauss' probability function.)

If, now, $a \Delta c_0 = c_0 \Delta a$, then these expressions can differ from each other only by an infinitely small amount in the second order. If, therefore, the time function $c_0(t) = c_0(0)\phi(t)$ is a good approximation of the stationary state, then the equation $a(t) = a(0)\phi(t)$ should apply for decrease in drop size with time. For the evaporation of the drop there can be substituted, as a first approximation, from (8)

$a(t) = \sqrt{a(0)^2 - kt}$. Here then:

$$f(t) = -\frac{da}{dt} = \frac{k}{2\sqrt{a(0)^2 - kt}}$$

and for t_3' there is obtained

$$a(0) = \frac{t_3' k}{\sqrt{a(0)^2 - kt_3'}}$$

from which

$$t_3' \approx 0.6 \frac{a(0)^2}{k} = 0.6 t_2$$

(t_2 is time of total evaporation.)

Then, return to a numerical factor 0.6 for equation (29); it follows from this, that there can be assumed a quasi-stationary course of evaporation of water droplets as a good approximation. This conclusion obviously agrees with the experimental results of Houghton.

Thus far, the evaporation of a single drop in an infinitely extended medium has been considered. In practice it is necessary to do, however, with a large number of droplets. In this case the evaporation of a drop takes place as though it were in a vessel with nonabsorbing walls, the volume of which vessel being equal to the average volume enclosing each drop. The rigorous solution of this problem is very difficult. Practically, for the small weight concentrations occurring in fog, that is, a large mean distance between the drops relative to their diameter, a simple approximation will serve. Then, assume that the droplet is in the midpoint of a spherical vessel of radius R with nonabsorbing walls. The distribution of concentration for different times is shown in figure 1 with dashed curves; the solid curves correspond to the stationary state (for absorbing walls with various vapor pressure, see sec. III).

(Translator's Note: The solid curve represents the stationary state for the same boundary conditions that exist at a particular instant in the nonstationary state.) It is easy to see that a curve of the first type must, in fact, lie under the curve of the second type with the same end-points. There results, therefore, for the velocity of evaporation in a known time $t + \Delta t$, a lower limit. (See equation (12).)

$$I_1 = \frac{4\pi a D (c_0 - c_{t+\Delta t})}{1 - \frac{a}{R}}$$

An upper limit can be obtained as follows. If the drop is placed at time t in an unbounded space with vapor concentration c_t , then its evaporation will take place more quickly than in the vessel. In time $t + \Delta t$ it will reach the following value:

$$I_2 = 4\pi a D (c_0 - c_t) \left(1 + \frac{a}{\sqrt{\pi D \Delta t}} \right)$$

(see equation (28)).

If the time interval Δt is chosen such that

$$1 + \frac{a}{\sqrt{\pi D \Delta t}} = \frac{1}{1 - \frac{a}{R}}$$

then the pictured curves are actually obtained, which do not intersect each other more than once. The equivalence of the two expressions for the amount of material evaporated in time interval Δt and stored in the gas atmosphere, respectively, yields:

$$\frac{1}{1 - \frac{a}{R}} 4\pi a D (c_0 - c_t) \Delta t \approx 4\pi \int_a^R [(c_{t+\Delta t}(r) - c_t(r))] r^2 dr$$

where $c_t(r)$ is the value c_t corresponding to the stationary distribution. By substituting the expression for $c(r)$ (equation (11)), there is obtained

$$\Delta c = c_{t+\Delta t} - c_t \approx \frac{3Da(c_0 - c_t)\Delta t}{R^3} \quad (32)$$

or, since

$$\Delta t \approx \frac{R^2}{\pi D}$$

$$\Delta c \approx (c_0 - c_t) \frac{a}{R} \quad (33)$$

At small values of a/R the stationary curves give a good approximation. With the same approximation (32) can be regarded as a differential equation. By integration, obtain

$$I = 4\pi a D c_0 e^{-3Da t/R^3} = I_0 e^{-3Da t/R^3}$$

This equation is obviously only applicable when the decrease in volume of the drop can be neglected (at very small vapor pressures or pressure differences). Otherwise, the system of differential equations (8) and (32) must be solved, which usually presents no difficulties.

VII. MOTION OF THE DROPLETS.

The exact calculation of the velocity of evaporation of a droplet moving with respect to the gas medium is scarcely possible. In a coordinate system relative to the drop (that is, drop at $r = 0$, $Z = 0$, $\alpha = 0$), this problem leads to the differential equation:

$$\frac{\partial c}{\partial t} = D \Delta c - \bar{v} \text{ grad } c \quad (35)$$

where with \bar{v} is meant the velocity vector of the gas stream, the value of this vector being determined in space by the nature of the flow.

Even in the simplest case of laminar flow, for which Stokes' law holds, and a stationary state, equation (35) is practically insolvable. It can be solved only for an infinitely small flow velocity: if this velocity is called V at a great distance from the drop, then let

$$c = \frac{c_0 a}{r} + V\phi$$

where the term $V\phi$ represents the disturbance of the concentration distribution caused by the flow. From (35) there is obtained (with $\partial c / \partial t = 0$):

$$DV\Delta\phi + \bar{v} \left(\frac{c_0 a \bar{r}}{r^3} + V \text{grad } \phi \right) = 0$$

and, since the last term can be neglected;

$$\Delta\phi = \frac{c_0 a}{Dr^3V} \bar{v} \bar{r}$$

If the Stokes expression for \bar{v} is substituted in this equation, the following result is obtained: At two points which are symmetrical with respect to the plane passing through the drop middle perpendicular to the flow direction, $\Delta\phi$ possesses the same absolute value, but reversed sign. Since further, ϕ vanishes on the surface of the drop and at infinite distance from it, then the application of the potential theory leads to the conclusion that at two diametrically opposite points on the surface $\text{grad } \phi$ has the same length and direction, that is, that the acceleration of the evaporation produced by the stream on one side of the drop is exactly compensated by the slowing down of the process on the other side.

This conclusion could approximately hold for a flow velocity, wherein the transfer of material by convection can be neglected in comparison with the transfer by diffusion -- at least at distances not too far from the drop, that is, when $c|\bar{v}| \ll D|\text{grad } c|$. If by substitution here $c = c_0 a / r$, there is obtained,

$$\frac{c_0 a V}{r} \ll \frac{D c_0 a}{r^2}, \quad \text{or} \quad \frac{aV}{D} \ll 1$$

$$(a \approx r)$$

Since it is known that $D \approx \frac{\eta}{\rho}$ (η is coefficient viscosity of the medium, ρ its density), then aV/D becomes the familiar Reynolds expression $\rho aV/\eta$. For small Reynolds numbers (for example, for free fall of fog droplets) a vanishingly small influence of the motion on the evaporation velocity would be expected. The validity of this conclusion obviously can only be decided by an experimental procedure.

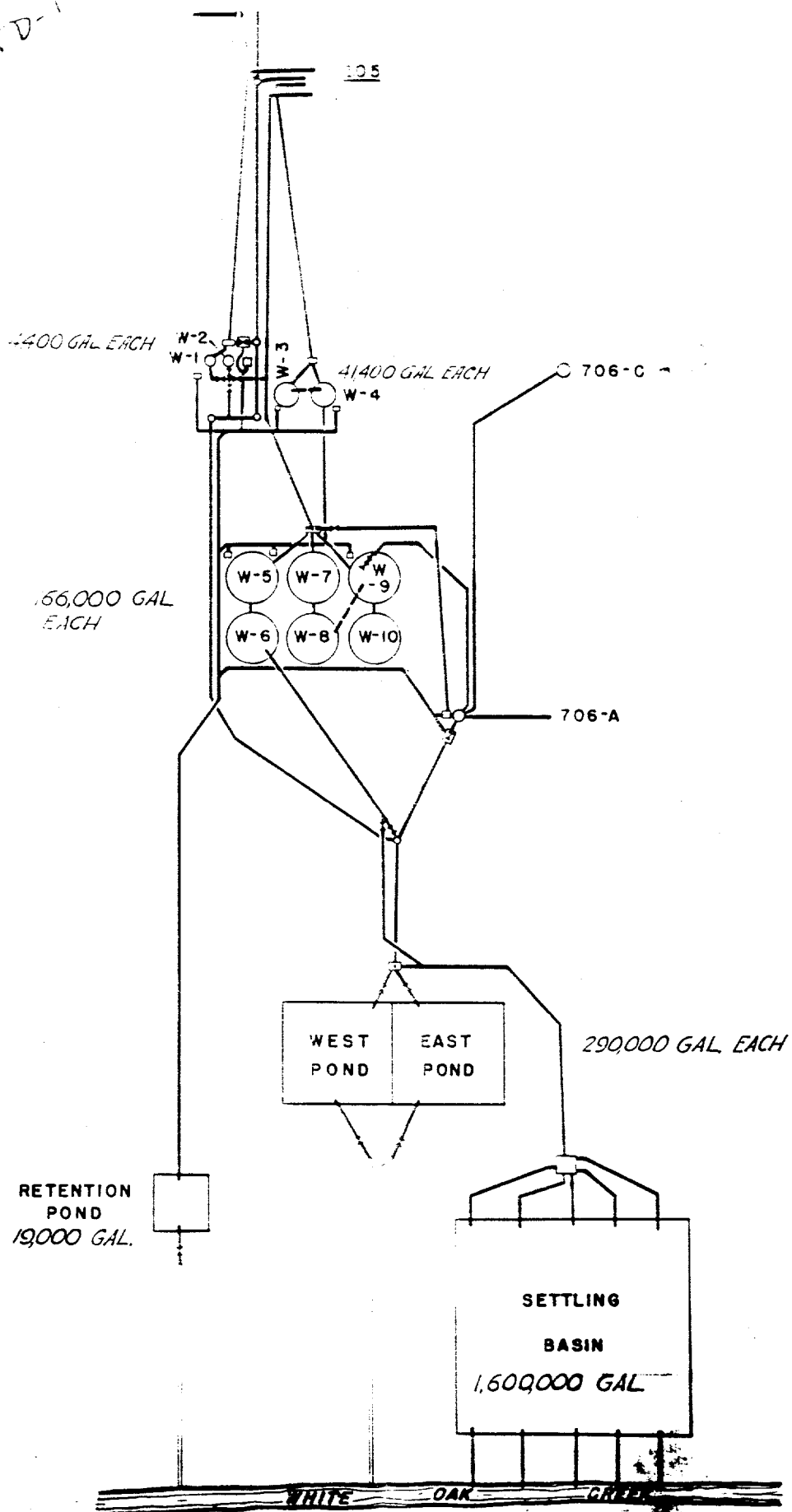
In conclusion, it should be said again that all the considerations and conclusions carried out here are also directly applicable to the reverse process - the growth of drops in a supersaturated vapor.

Translation by John Nelson Howard and Mitchell Gilbert,
National Advisory Committee
for Aeronautics.

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USE FOR
TD-1



TS-12

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Oak Ridge National Laboratory
Technical Division
Chemical Process Development Section

~~Proprietary~~

FINAL REPORT

Title

Evaporation Entrainment

Author

W. K. Eister

Abstract

The evaporation entrainment as measured in semi-works tests varied from 0.002 to 0.8%.

Work by: R. J. Klotzbach, R. E. Leuze

Secret Notebook No.: —

Period of Work: 1945 - 1946

Date of Report: May 25, 1948

- Distribution:
1. C.E.Winters ~~CONFIDENTIAL~~
 2. F.L.Steahly
 3. W.K.Eister

The entrainment during pot evaporation was determined in the homogeneous pile, and "23" separation studies. ~~These~~ solutions were evaporated; water, sodium carbonate and nitric acid. The percent entrainment was determined in the Equipment No. 1 runs by spiking with Ba-Ia tracer, and in Equipment No. 2 runs "23" was analyzed. The results in Table 1 are not consistent but the following conclusions are indicated:

- (1) Entrainment varied from 0.002 to 0.80%.
 - (2) Increasing the evaporation rate increased the entrainment.
 - (3) Entrainment increased as the solution changed from water to carbonate. The decrease in entrainment for the acid solution may have been due to the change in equipment.
- ✓
C. L.

Table 1

Evaporation Entrainment

Equip- No.	Sol'n	Evaporation Rate lb/m x sq.ft.	% Entrainment
1	water and Ba tracer	25	0.17
		64	0.10
		97	0.38
		130	0.29
1	0.3M Na ₂ CO ₃ and Ba tracer	37	0.14
		56	0.80
		59	0.58
		70	0.77
2	0.1M HNO ₃ and Ba tracer	6.4	0.002
		127.0	0.14

Equipment No.1: pot, 10" diameter x 36" high
free board, 24" average
vapor take-off, 3" pipe with 2' rise over the top of the
pot.

Equipment No. 2: pot, 7.5" diameter (average) x 26" high (conveal tank)
free board, 21" average
vapor take-off, 2" pipe with 3.75' rise over the top of
the pot. Baffles over pot opening.

50

M E M O R A N D U M

April 7, 1948

To: S. McLain

From: F. L. Culler

Subject: Evaporation of Highly Radioactive Wastes From
The 1200 Areas

In developing the first concepts of the 1200 Area waste storage and disposal system, evaporation of the highly active first and second cycle raffinates to near saturation with respect to the salting agent, aluminum nitrate, has been proposed as the method of obtaining smaller volumes of waste for permanent storage. This concept, in view of past experience here and at other sites, warrents further investigation and development.

As you know, we had planned on discharging the condensates from this evaporation to collection tanks from which the wastes could be sent to another evaporator or directly to the retention pond. The design of the chemistry cycle will be such that no activity is discharged from the chemical areas.

Data from three sources recently reviewed indicates that the carry-over of activity during evaporation may be great enough to cause concern if special precautions are not taken. From a dilute solution of cerium tracer, using a low evaporation rate and a packed deentraining column, Knolls reports carry-over of approximately 0.04% of the activity. Runs with this tracer were discontinued after about 70% of the initial solution had been evaporated because of severe bumping. The quarterly report for the past period reported a 0.03 to 0.05% uranium loss to condensate during the concentration of the first cycle strip product. Data on evaporation of 23 strip product from batch extraction work done in the semi-works gave a 0.05% carry-over of uranium. This number, 0.05%, seems to be rather well substantiated.

Each batch of first cycle raffinate will contain 34,000 curies of mixed fission product activity. Using the 0.05% carry-over, the condensates from the first evaporation will contain about 13 curies of activity. The condensate from a second evaporation would contain approximately 50 mc of activity. The 0.05%

carry-over may be low because:

- 1) The first cycle raffinates will contain near saturation quantities of aluminum.
- 2) Volatilization of some of the active constituents of the raffinate may occur.

Consideration of the above figures, and the general lack of information on evaporation of active wastes indicates that a program on evaporator design could well be started here at the Laboratory. In talking to I. R. Higgins of Section I, who is now embarking upon an investigation of waste decontamination via ion exchange, it was suggested that this evaporation work might be done in conjunction with his efforts. We would like very much to have a more stable basis on which to design the waste disposal system before this issuing of the design report. It is suggested that information from Knolls and other projects where investigations on evaporation are proceeding be accumulated and applied to our uses. The design of the 1200 and 1300 Area waste systems may be drastically affected by recommendations resulting from such an investigation.

F. L. Culler
Process Design Section

Distribution: 1. S. McLain
2. W. K. Eister ✓
3. F. L. Culler

6078 30
7/17/48

OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee

Technical Division

PROBLEM ASSIGNMENT

Problem No.: TD-12

Date: May 25, 1948

Title: Decontamination of Oak Ridge National Laboratory Plant Chemical Waste

Object: To develop a process for further decontamination of the non-uranium-containing plant wastes now discharged into White Oak Creek.

Discussion: Activities now discharged into White Oak Creek must be reduced. Proposals include an efficient precipitation, settling and filtering operation, followed with ion-exchange to remove soluble activities. Higgins and Orr are working on ion-exchange at present. The precipitation and separation problem needs attention on laboratory and semi-works scale development. Close cooperation is necessary with the Health Physics Division, and the Operations Department.

It is suggested that two men be assigned for three month scouting investigation, one investigating precipitation chemistry, and one settling and filtration. Definite proposals for large-scale treatment should then be made.

Assigned: Section I.

Distribution:

Hawkins, W. H.
Kuffman, J. R.
Nyger, J. A.
Lyon, R. H.
McLain, S.
Peterson, H. D.
Reid, D. E.
Rucker, C. W.
Steenly, F. L. ✓
Winters, J. E.

Estimated Cost: Labor: 6 Man-months
Materials:
Total:

Account No.: H426L

Approvals:

orig./H.D.P.
H. D. Peterson

orig./S.McL
Stuart McLain

To: F. L. Steahl - *FLS*

Date: July 8, 1948

From: I. R. Higgins

Report Period: 6-10-48 to 7-10-48

Distribution: (1) FLS (2) IRE (3) RCR (4) FLS

Problem No. TDCI- TD-12

Part I

MONTHLY REPORT

Title: Evaporation of ORNL Non-Uranium Bearing Chemical Waste

Work by: I. R. Higgins

Secret Notebook No. CL-1670

SUMMARY

Plans are underway for setting up an experimental evaporator for concentrating ORNL non-uranium bearing waste. At present about 4000 gallons per day containing 1 to 5 curies of activity is being dumped into the settling pond from W-6. It was first decided to evaporate this waste, but a hasty calculation revealed that W-6 would be full of sodium salt in about 1 year of operation. Since the bulk of the storage space would be occupied by an inert salt it was decided to evaporate the waste before neutralization and save tremendously on storage space. At present, an experimental evaporator is being designed, waste samples are being analyzed, and corrosion tests being run. When the evaporator is completed, studies will be made on, volume reduction, corrosion, scaling, heat efficiency, and entrainment losses.

INTER-COMPANY CORRESPONDENCE

(COMPANY) COMPANY CARBIDE AND CARBON CHEMICALS CORP. LOCATION

Post Office Box P
OAK RIDGE, TENN.

LOCATION 1. Blain (3)
703-a

DATE July 2, 1948

ANSWERING LETTER DATE

ATTENTION
COPY TO

1. J. Counlen
2. Steahly
File

SUBJECT

Memorandum of D. G. Reid
of June 25, 1948, regarding
Problem Assignment TD-3

The data of Reid on his vessel are very interesting. From data obtained on Naval vessel boiler feed water evaporators, entrainment of 0.01% is commercially attainable; however, it has been Navy experience (considerable) that only a very few manufacturers have been able to supply them with evaporators meeting this specification. Apparently, they have tested a number of commercial products, including all sorts of entrainment separators, the data upon which would be available to us for the cost of a trip to Washington, D. C.

Since apparently the experience has been that the entrainment is a sharp function of the baffle details, and the vapor velocity, I plan to ask Don Reid for these additional details so that they may be included in our findings.

C. L. Winters

CEH:tkk